

# A study on Cluster Based Routing Protocols in Wireless Sensor Networks

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**Abstract** - Newest advancements in micro-electro-mechanical-system (MEMS) and wireless communication technology unlock the way for the development in applications of wireless sensor networks (WSNs). Wireless sensor network is comprised of vast number of minute and cheap devices known as sensor nodes. The sensor nodes work together by a lot of wireless strategies and these strategies are administered by routing protocols. Performance of sensor networks mainly depends on the routing protocols which are request based. Based on structure of network routing protocols in WSN can be largely classified into three categories: flat routing, hierarchical or cluster based routing, and location based routing. Due to sure advantages, clustering is gratifying as a lively stem in routing technology. In this paper, authors have been reported a complete survey on cluster based routing protocols in wireless sensor networks. We sketch the merits and limitations of the clustering schemes in WSNs, and propose a classification of cluster based routing methods. Lastly, we summarize and bring to a close the paper with some future directions.

**Keywords** - wireless sensor networks; cluster based routing; sensors; taxonomy; communication strategy.

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## INTRODUCTION

The series of wireless sensor networks [1, 2] was at first annoyed by military applications. While, wireless sensor networks are at the present time used in many civilian application areas like: monitoring, tracking, mechanization, traffic control, and healthcare applications. The WSN is collected of wireless modules called sensor nodes. The structural design of sensor node is shown in figure 1. The key components [3] of a node are: a micro sensor, a microchip, a memory, a battery, and a transceiver to converse with rest of the networks. Because of the boundaries on the power provide, transmission bandwidth and processing ability, well-organized routing becomes a vital issue in wireless sensor network. Routing protocols [4, 5] in WSN are accountable for discovering and maintaining energy well-organized routes in order to create communication dependable and well-organized. On the basis of literature review on network structure based routing schemes, WSNs routing protocols can be separated into three categories: flat routing, hierarchical or cluster based routing and location based routing.

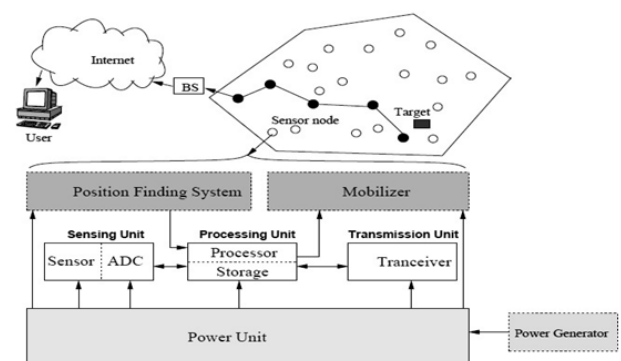


Figure 1. Sensor node architecture (source: [4])

In flat networks, every node plays the same position and nodes work together to execute the sensing task [4]. Flat routing protocols [6, 7] are fairly effectual in small scale networks. Though, they are quite undesirable in large scale networks because of resources limitation. In hierarchical routing, nodes carry out different tasks and are characteristically grouped into clusters based on exact requirements.

This means that formation of clusters and assigning exact task to cluster heads (CHs) can considerably contribute to scalability, lifetime, and energy efficiency. In this paper, authors present a sufficient survey of a variety of cluster based routing protocols planned in current years. The rest of the paper is prepared as follows. Describes the routing protocols in wireless sensor networks, describe the cluster based routing protocols, and evaluate the different cluster based routing protocols in WSN. Some open issues are discussed in section 5 and section 6 concludes the paper.

## ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS

Routing is a technique to find out a path between the source node and the destination node [5]. Routing in WSN is actually demanding due to the inherent characteristics that distinguish these networks from other networks. The design of routing protocols in WSNs is affected by a number of demanding factors. The efficient communication can be achieved in WSNs by overcoming these factors.

### Design Challenges of Routing Protocols in WSNs

Routing protocols [4, 7] in WSNs are accountable for discovering and maintaining energy well-organized routes in the networks, in arrange to make communication reliable and well-organized. Due to the limitations in the type of network, the major aim of routing protocol plan is extending the network life time by keeping the sensors alive as much as possible. This subject results in observance the network connected for a extended period of time. There are some demanding factors which are significant in designing routing protocols. These are given as:

**Node deployment:** Deployment application dependent and affects the performance of the routing protocols. It can be physical or randomized [4, 6]. In the first plan, the nodes are physically placed and data is routed through *predestined* paths. In physical deployment, coverage of area is pleased with careful option of node density. Though, this is high-quality choice when nodes are expensive and their operations are prejudiced by their locations, it is not good for cruel environments [8]. On the other hand, in chance deployment, the nodes are dotted randomly. If the application is connected to event detection, then it is well-organized to have a random node deployment to get effective results [9, 10].

**Energy consumption:** The major aim of routing protocols is to express data in the middle of sensors and go under in well-organized manner. Every sensor node consumes energy in sensing, dispensation, receiving and transmitting information [2]. In the middle of these data transmission is the most energy consuming task [11]. Since, the sensor nodes have

incomplete energy resources, energy reduction of some nodes results in great topology and network connectivity changes, reorganization of network and finding new routes. So, there is a require to design routing protocols that can accommodate the tradeoff between energy optimization and correctness [12, 13].

**Nature of node:** In WSN, the nodes that are dotted over the environments can be either homogeneous or heterogeneous. Homogeneous nodes have the similar capabilities such as, variety of transmission, battery life, and dispensation capacity while heterogeneous nodes have dissimilar capabilities [4]. The majority of the network structural design assumes that the sensor nodes are motionless. However, mobility of base stations as well as of nodes is essential in several applications [14].

**Coverage:** In WSNs, every node prevails a sure view of the environment. A given sensor's vision of the environment is incomplete both in range and in accuracy. Hence reporting area is essential design issue [11].

**Scalability:** The number of nodes deployed in the field may be changeable i.e. few numbers to few thousands. The routing protocol is necessary to be able to work with huge amount of nodes [4, 11]. When the number of nodes is wide, it is infeasible that each node preserve a global knowledge of network topology.

**Quality of service (QoS):** The routing protocols should be able to provide sure level of QoS that is necessary by the application. The QoS parameters can be bandwidth, release delay, throughput, jitter etc.[15]. For example, target discovery and tracking applications requires low broadcast delay for the time responsive data. While, multimedia networks requires high throughput [16].

**Application:** The routing protocols are very application exact. In other words, diverse situation or network environments require different routing protocols. From the application's point of view, data can be composed from the environment using a variety of methods such as, time driven, event driven, and query driven methods. In time driven methods, the sensor nodes send their data occasionally to BS or Gateways. In event driven methods, sensor nodes report the collected data when the event occurs. Finally, in query driven methods, the BS requirements the data from the nodes and send a query [4, 16].

### Classification of Routing Protocols in WSNs

In WSNs, the network layer is used to put into practice the routing of incoming data. In multi-hop networks, the source node cannot arrive at the sink in a straight line. So, middle nodes have to communicate their packets. The completion of

routing tables gives the explanation. WSN routing protocols can be classified into five ways, according to the way of establishing the routing paths, according to the network arrangement, according to the protocol process, according to the maker of communications, and according to how a protocol selects a next hop on route of forwarded message. The classification of routing protocols is shown in figure 2.

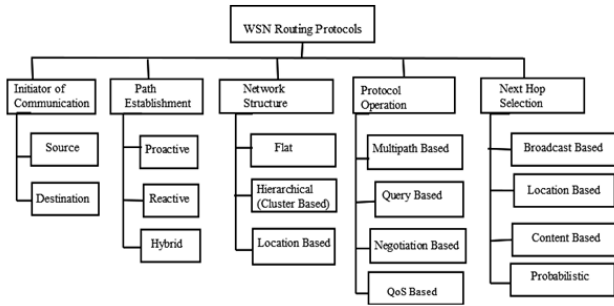


Figure 2. classification of routing protocols in WSNs

The network structure based routing protocols are categorized as: flat based, hierarchal based (cluster based), and location based routing protocols. In flat based routing, each sensor node plays similar role. In hierarchal based routing, sensor nodes have dissimilar roles. So, when network scalability and well-organized communication is wanted, hierarchal or cluster based routing is the best choice.

**CLUSTER BASED ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORKS**

The cluster based routing [17,18,19] is power well-organized method in which nodes those having high energies are randomly chosen for processing and distribution data while nodes those having low energies are used for sensing and distribution information to the cluster heads (CHs). This possession of cluster based routing contributes to the scalability, lifetime maximization, and energy minimization. The cluster based routing protocols plays a essential role in achieving request exact goals [20, 21, 22]. The cluster based routing protocols are classified into three broad **categories**: block cluster based, grid cluster based, and chain cluster based routing protocols. The classification of cluster based routing protocols is shown in figure 3.

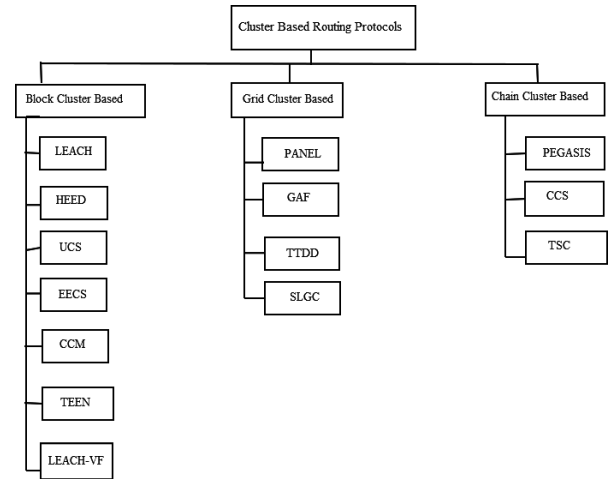


Figure 3. categorization of cluster based routing protocols in WSNs

The well-liked block cluster based routing protocols are: LEACH, HEED, UCS, EECS, CCM, TEEN, LEACH-VF etc as shown in figure 3. The merits and limitations of block cluster based routing protocols are given in table 1. The well-liked grid cluster based routing protocols are: PANEL, GAF, TTDD, SLGC etc as shown in figure3. The merits and limitations of grid cluster based routing protocols are given in table 2. The well-liked chain cluster based routing protocols are: PEGASIS, CCS, TSC etc as shown in figure 3. The merits and limitations of these protocols are given in table 3.

Table 1. Outline of merits and limitations of block cluster based routing protocols

Algorithm	Merits	Limitations
LEACH [23]	<ul style="list-style-type: none"> <li>Every node has corresponding chance to become cluster head but cannot be selected as cluster head in following round so load is shared between nodes</li> <li>LEACH uses TDMA so it keeps CHs from pointless collisions</li> </ul>	<ul style="list-style-type: none"> <li>LEACH use solitary hop communication so it can not used in big scale networks</li> <li>CHs are chosen on the basis of probability so uniform sharing cannot be ensured and it cannot provide load balancing</li> </ul>
HEED [24]	<ul style="list-style-type: none"> <li>Fully distributed routing scheme</li> <li>HEED achieves load balancing and uniform CH distribution</li> <li>HEED achieve high energy efficiency and scalability by communicating in multi-hop way</li> </ul>	<ul style="list-style-type: none"> <li>Unbalanced Energy utilization due to more CH generation</li> <li>Huge overhead due to multiple rounds</li> <li>Additional overhead due to numerous epochs</li> </ul>

UCS [25]	<ul style="list-style-type: none"> <li>Nodes in cluster can be changeable</li> <li>UCS is bi-layered model and two-hop inter cluster communication</li> </ul>	<ul style="list-style-type: none"> <li>It is limited by assumptions that CHs are prearranged as well as network is not homogeneous.</li> <li>Remaining energy of node is not considered and not enough for large range networks</li> </ul>
EECS [26]	<ul style="list-style-type: none"> <li>EECS constructs more balanced network in term of energy utilization and communication load</li> <li>Use active sizing of clusters</li> </ul>	<ul style="list-style-type: none"> <li>Lot of overhead due to global information for communication</li> <li>Single hop communication consume lot of energy</li> </ul>
CCM [27]	Less energy utilization compared with LEACH	Chain head collection criterion
LEACH-VF [28]	<ul style="list-style-type: none"> <li>Solve the problem of area with overlapped sensing coverage and sensing hole</li> <li>In LEACH-VF some nodes can be moved to reporting inside the cluster</li> </ul>	<ul style="list-style-type: none"> <li>Poor energy efficiency</li> <li>Load balancing is not up to the mark</li> </ul>
TEEN [29]	<ul style="list-style-type: none"> <li>Data transmission can be controlled by varying two thresholds</li> <li>Well suited for time serious applications</li> </ul>	<ul style="list-style-type: none"> <li>Whenever thresholds are not assemble the node will not communicate</li> <li>Data may be lost if CHs are not able to converse with each other</li> </ul>

**Table 2. Outline of merits and limitations of grid cluster based routing protocols**

Algorithm	Merits	Limitations
PANEL [30]	<ul style="list-style-type: none"> <li>PANEL is energy competent that make sure load balancing and long network life time</li> <li>Supports asynchronous applications</li> </ul>	<ul style="list-style-type: none"> <li>Clusters are prearranged</li> <li>To determine geographic location information, special conditions are needed, which is not always accessible</li> </ul>
GAF [31]	<ul style="list-style-type: none"> <li>GAF boost the network lifetime by saving energy</li> <li>Routing loyalty is maintained</li> </ul>	<ul style="list-style-type: none"> <li>Huge traffic injection and delay is not predictable</li> </ul>
TTDD [32]	<ul style="list-style-type: none"> <li>Resolve the many mobile sinks and moving problem of sink in large scale WSNs</li> <li>Appropriate to event detecting WSNs among irregular data traffic</li> </ul>	<ul style="list-style-type: none"> <li>Large latency</li> <li>Low energy efficiency</li> <li>TTDD require sensor nodes to be stationary and location aware</li> </ul>
SLGC [33]	<ul style="list-style-type: none"> <li>Lower energy consumption in SLGC compared to LEACH</li> </ul>	<ul style="list-style-type: none"> <li>Large overhead due to complex data communication</li> </ul>

**Table 3. Outline of merits and limitations of chain cluster based routing protocols**

Algorithm	Merits	Limitations
PEGASIS [34]	<ul style="list-style-type: none"> <li>Energy load is spread consistently</li> <li>Decrease overhead due to dynamic cluster configuration</li> <li>Decrease number of data broadcast</li> </ul>	<ul style="list-style-type: none"> <li>Long delays reason a node to become block</li> <li>Network is not very scalable</li> <li>Not appropriate for time varying topologies</li> </ul>
CCS [35]	<ul style="list-style-type: none"> <li>Energy consumption is reduced</li> <li>Reduced data flow from BS in CCS</li> </ul>	<ul style="list-style-type: none"> <li>Disturbed energy consumption</li> <li>Big delay due to long chain</li> </ul>
TSC [36]	<ul style="list-style-type: none"> <li>TSC reduces disused data transmission in network by breaking long chains into smaller chains</li> </ul>	<ul style="list-style-type: none"> <li>Node distribution in disturbed</li> </ul>

**COMPARISON**

Table 4 summarizes the evaluation between admired cluster based routing protocols on the root of energy efficiency, delivery delay, cluster stability, load balancing, and algorithmic complexity.

**Table 4. Evaluation between popular clusters based routing protocols**

Scheme Name	Energy Efficiency	Delivery Delay	Cluster Stability	Scalability	Load Balancing	Algorithm Complexity
LEACH	Very low	Very small	Medium	Very low	Medium	Low
HEED	Medium	Medium	High	Medium	Medium	Medium
UCS	Very low	Small	High	Low	Bad	Medium
EECS	Medium	Small	High	Low	Medium	Very high
CCM	Very low	Small	High	Very low	Medium	Medium
LECH-VF	Medium	Small	High	Very low	Medium	Medium
TEEN	Very high	Small	High	Low	Good	High
GAF	Medium	Very small	Medium	High	Medium	Medium
PANEL	Medium	Medium	Low	Low	Good	High
TTDD	Very low	Very large	Very high	Low	Good	Low
SLGC	Medium	Very small	Medium	Very low	Medium	Medium
PEGASIS	Low	Very large	Low	Very low	Medium	High
CCS	Low	Large	Low	Low	Very bad	Medium
TSC	Medium	Medium	Medium	Medium	Bad	Medium

**ISSUES IN CLUSTER BASED ROUTING PROTOCOLS**

The large amount research work has been complete to query the drawbacks of clustering techniques and to get better the independence of cluster based routing methods but there are still several issues to be addressed for the well-organized use of cluster based routing techniques [37,38,39,40]. The number of open issues requires to be addressed are:

- **Computation and collection of cluster heads (CHs):** CH is utility of computation and communication energy model for the clustering schemes. If the multi hop scheme is used then CHs count hypothetical to be revised. The presentation and ease of use of adjacent CHs is a significant factor for relaying the data of clusters. As a result, CH role in rotation of neighboring clusters must be measured as dominant factor in selection procedure of CH.
- **Scalability:** In a small number of large scale deployments, it is frequently desirable to increase the monitoring area in the middle of new nodes. So, cautious observations are required to ensure the flexibility and scalability of clustering techniques.
- **Topology of network:** Topology changes payable to defensive situation in realization of WSNs. So, it is significant to focus on the power of clustering methods.
- **Fault tolerance:** Transient responsibility management payable to temporal link failures needs much more attention.
- **Redundancy management:** Minimizing the use of particularly redundant nodes for

building dependable and capable relay backbone. The mutual data of CHs relayed to BS must be investigated further.

## CONCLUSION

Wireless sensor networks have fascinated a great deal anxiety for both civil and military applications. Examples consist of ecological monitoring, border defense, battle-ground, and security observation. In these applications a enormous number of sensors are desirable, requiring cautious architecture and network organization. To support scalability, grouping nodes into clusters has been popular technique in WSNs. In this work, we surveyed the position of research and classified the dissimilar clustering methods. This paper classifies the classification of cluster based routing protocols. In this work, we spotlight on the merits and limitations of diverse cluster based routing protocols and represent them in tabular form. On the basis of comparison between diverse schemes, it is obvious that cluster based routing protocols are helpful in performance development of wireless sensor networks. This paper will be very helpful for the research group those are involved in the development, alteration or optimization of routing algorithms for WSNs.

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